International Journal of Agricultural Sustainability

ISSN: 1473-5903 (Print) 1747-762X (Online) Journal homepage: www.tandfonline.com/journals/tags20

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To cite this article: Inés Gutiérrez-Briceño, Irene Pérez-Ramírez , Carolina Yacamán-Ochoa , Dario Lucantoni , Beatriz Vizuete , Violeta Hevia , José A. González , Gerald Schwarz & Marina García-Llorente (2025) Unravelling agroecological transitions: a multidimensional study of the horticultural sector in Madrid, International Journal of Agricultural Sustainability, 23:1, 2551423, DOI: 10.1080/14735903.2025.2551423

To link to this article: https://doi.org/10.1080/14735903.2025.2551423

INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY
2025, VOL. 23, NO. 1, 2551423
https://doi.org/10.1080/14735903.2025.2551423

Unravelling agroecological transitions: a multidimensional study of the horticultural sector in Madrid

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ABSTRACT

The growing need for alternative agri-food systems has become prominent, emphasizing local alternatives that prioritize long-term socio-ecological sustainability. Agroecology represents a compelling alternative, promoting the transition toward sustainable food production that balances farmers 'profitability with biodiversity conservation and the maintenance of ecosystem services. This research assesses the agroecological transition among selected horticultural farms in the Community of Madrid and analyse key barriers that hinder the sector's progress in embracing agroecology. Utilizing the FAO's Tool for Agroecology Performance Evaluation (TAPE), we conducted 26 interviews to assess farms against the 10 Elements of Agroecology. Our findings reveal that the sector has a long journey in the agroecological transition towards sustainability. The findings highlight a non-linear progression in agroecology, with each farm developing its unique path adapted to its specific context. Among the most frequently cited challenges are economic constraints and limited access to land. Drawing inspiration from existing initiatives, we offer insights for reshaping and guiding our agri-food systems towards sustainability. By presenting a comprehensive analysis of the agroecological transition status and barriers within the horticultural sector, this study contributes to the broader discourse on sustainable food systems and informed interventions and policy recommendations.

ARTICLE HISTORY
Received 11 June 2024
Accepted 7 August 2025

KEYWORDS
Agroecological transition; horticulture; agri-food system; TAPE tool; barriers

1. Introduction

The urgency of developing alternative agri-food systems has become evident with the prevailing agricultural paradigm (Anderson & Maughan, 2021), which underscores the pressing necessity for localized alternatives and to prioritize long-term sustainability (Runhaar, 2025; Wezel et al., 2014). This urgency stems from the myriad challenges posed by conventional agriculture, including environmental degradation, loss of biodiversity, and socioeconomic inequities (Matson et al., 1997; Power, 2010; Tscharntke et al., 2012). In response to these challenges, the call for alternative agri-food systems has gained traction, advocating for approaches that seek to balance ecological, economic, and social factors (Altieri, 1989; IPBES, 2019). One such alternative that has gained attention is agroecology, a holistic paradigm articulated as a practice, science, and social movement aiming to transform the global agri-food system (Méndez et al., 2013; Wezel et al., 2014). From socio-ecological perspective, agroecology represents a transformative vision (HLPE, 2019), recognizing the intricate relationship within social and natural systems throughout the entire agri-food system and placing power, governance, and democracy at the centre (Leippert et al., 2020). Rooted in diverse ecological processes, agroecological farming practices embody methods that contribute to the resilience and

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/14735903.2025.2551423.

sustainability of agroecosystems (Wezel et al., 2014). However, agroecology transcends farming practices, intertwined with political dimensions and commitment to social activism (Anderson et al., 2019).

Therefore, it becomes important to examine the mechanisms facilitating the transition from the prevailing agricultural paradigm to agroecological food systems. In this context, the term 'agroecological transition' refers to the transformation from productivist-oriented agriculture to an approach grounded in biodiversity and social considerations (Duru et al., 2015). This ecologization of agri-food systems implies a systemic transformation at different scales (Darmaun et al., 2023; Madsen et al., 2021) involving multiple stakeholders (Magrini et al., 2019) who seek synergistic models between conservation efforts and the productive sector. This transformation includes political, economic, environmental, and socio-cultural changes in practices, rules, values, and institutions (Madsen et al., 2021; Pitt & Jones, 2016). Researchers are actively working to develop effective models and methodologies that help stakeholders to design and implement this transition (Anderson et al., 2019; Gliessman, 2020; Gliessman et al., 2007; Hill & MacRae, 1995; Rogers, 1983). Hill and MacRae (1995) introduced the Efficiency-Substitution-Redesign (ESR) framework, originally developed in the context of pest management and organic systems, which has now found applications in agroecology. Gliessman et al.'s (2007) transition framework is structured across five levels, beginning with addressing resource use efficiency (Level 1) and followed by the substitution of inputs (Level 2). Level 3 involves the redesign of the farming system to increase environmental quality and synergies between the farm and landscape. Level 4 and 5 encompass the whole agri-food system, first by establishing new relationships between producers and consumers, and finally, building a new global agri-food system. These frameworks are valuable as they propose concrete strategies for transitioning from the conventional to a sustainable agri-food system, yet we need tools to measure and assess the various steps along this path.

Based on these frameworks, researchers have developed methodologies to evaluate agroecological transitions, considering the multidimensionality of the process (Darmaun et al., 2023; Mottet et al., 2020; Trabelsi et al., 2019). This assessment explores the benefits, limits, and barriers inherent in agroecological transitions across different contexts, contributing to knowledge on strategies to accelerate the transition process (Dendoncker et al., 2018). This information, along with the developed methods is crucial for strategic stakeholders such as farmers, decision-makers, researchers, and agricultural technicians (Darmaun et al., 2023; Mottet et al., 2020). However, assessing agroecological transitions is challenging due to the inherent heterogeneity and evolution of these processes over time (Wezel et al., 2020). Consequently, empirical data on agroecological transitions remains scarce (Guzmán et al., 2012; Méndez et al., 2017). The complexity is further compounded by the nature of agroecology, which is based on localized processes tailored to the specific realities of territories (Dendoncker et al., 2018; Hatt et al., 2016; Magrini et al., 2019). Thus, establishing a cohesive body of evidence for assessing agroecological transitions is intricate, requiring careful consideration of diverse local contexts and the dynamic nature of the agroecological concept itself.

To address the complexity of measuring agroecological transitions, the Food and Agriculture Organization of the United Nations (FAO) initiated multi-stakeholder and international dialogues on the multidimensional performance of agroecology (FAO, 2018). This resulted in the articulation of the 10 elements of agroecology (FAO, 2019) and the formulation of an analytical framework to support the transformation of agroecosystems and food systems (Barrios Latorre et al., 2023). In 2019, FAO launched the Tool for Agroecology Performance Evaluation (TAPE), developed with scientists, civil society, governments, and producers' organizations (FAO, 2019). TAPE is a framework for characterizing agroecological transitions and for measure the multidimensional performance of agroecology (Mottet et al., 2020). Its capacity to delineate key actions for promoting transitions makes it an interesting resource for stakeholders seeking to navigate the complexities of agroecological transformations (Lucantoni et al., 2023).

Building upon this context, the main goal of this research is to explore the horticultural sector in the Community of Madrid from a holistic perspective by interviewing farmers using the TAPE framework. Therefore, the specific goals of our research are: (i) the assessment of the agroecological transition status of selected horticultural farms and (ii) the analysis of the main barriers in the agroecological transition faced by the sector. Our results are expected to provide comprehensive understanding of the agroecological transition within specific regions, shedding light on the current state and potential trajectories of the horticultural sector. These insights are crucial for policymakers, agricultural practitioners, and stakeholders, providing a foundation for informed decision-making, sustainable agricultural practices, and the development of

effective strategies to foster agroecological transitions for enhanced environmental and socio-economic outcomes.

2. Methods

2.1. Study area and farm selection

Our study was conducted in the Community of Madrid (Spain), where the agricultural sector has gradually declined since the 1960s due to factors such as the continuous urban expansion of the capital and the abandonment of agrarian activities (Soler & Fernández, 2015). Nonetheless, agriculture remains significant in the region, covering 28% of the territory (del Valle et al., 2019). Despite the overarching challenges, there has been a noteworthy resurgence in agroecological initiatives over the past decade, particularly in the horticultural sector, where approximately 53,7% of ongoing initiatives are concentrated (del Valle et al., 2019; García-Llorente et al., 2019; Márquez-barrenechea et al., 2020). Notably, only 6.0% of the agricultural surface in Madrid is dedicated to horticulture, mainly positioned along river terraces in the southeastern part of the region (del Valle et al., 2019). This juxtaposition of agricultural decline and the rise of agroecological initiatives highlights a shift towards sustainability and resilience in the face of urbanization and changing agricultural landscapes.

The study was conducted in 12 municipalities in the southern area where horticultural production remains significant, particularly among the main river watersheds. This region includes fertile lowlands along major river basins such as the Tajo, Jarama, Tajuña or Alberche, which have historically supported horticulture due to their soil and water availability. Despite increasing urbanization and the overall decline of agriculture in the region (Garrido & Chuliá, 2020), these areas continue to sustain a small but diverse horticultural sector that plays a key role in local food systems and territorial identity (Pérez-Ramírez et al., 2019). To ensure a representative sample of the horticultural sector, we selected farms based on a set of criteria that prioritized diversity in location, farm size and management practices (ranging from conventional to agroecological). This approach allowed us to capture a wide range of production methods and socio-economic conditions within the study area. We began by reviewing prior research conducted in the region by the research team (see Palomo-Campesino et al., 2021), which helped us to identify initial key actors. This was followed by exploratory field visits across municipalities such as Aranjuez, Ciempozuelos, Perales de Tajuña and Villa del Prado, among others, to refine the sampling and capture local heterogeneity. From there, we initiated a snowball sampling process (Prell et al., 2010), which was further complemented by leveraging personal contacts and local networks to reach farmers who may not be formally affiliated with agroecological initiatives but whose practices align with sustainable agricultural principles. This strategy ensured the inclusion of a broad spectrum of producers, ranging from those practicing conventional horticulture to those engaged in agroecological and alternative food production models.

From the initial pool of farmers contacted, we ultimately secured the participation of 26 horticultural farms willing to contribute to the study (Figure 1). The mean farm size was 5.76 (SD = 9.05 ha), with sizes ranging from 0.5 to 40 ha, indicating substantial variation.

2.2. Data collection

The Tool for Agroecology Performance Evaluation (TAPE) was used to assess the agroecological transition in the horticultural sector in Madrid. The methodology proposed for TAPE assessment consists of a face-to-face interview with farmers at their farms (Mottet et al., 2020). This tool is structured into four steps to assess the multidimensional performance of agroecology. Step 0 describes the farming system and analyses the territorial context and key drivers influencing the agroecological transition. Step 1, known as the Characterization of the Agroecological Transition (CAET), scores the 10 Elements of Agroecology developed by FAO (2019). This step is the to assesses the transition level of the agricultural system – horticulture in this case – highlighting farms 'strengths and weaknesses. It uses a survey with a list of 36 indices with descriptive scales from 0 to 4. Systems with high scores across are considered more advanced in agroecological transition (Mottet et al., 2020). Management practices cover elements like Diversity, Resilience, Synergies, Efficiency, and Recycling, while the social aspects are covered with the elements of Human and Social Values,

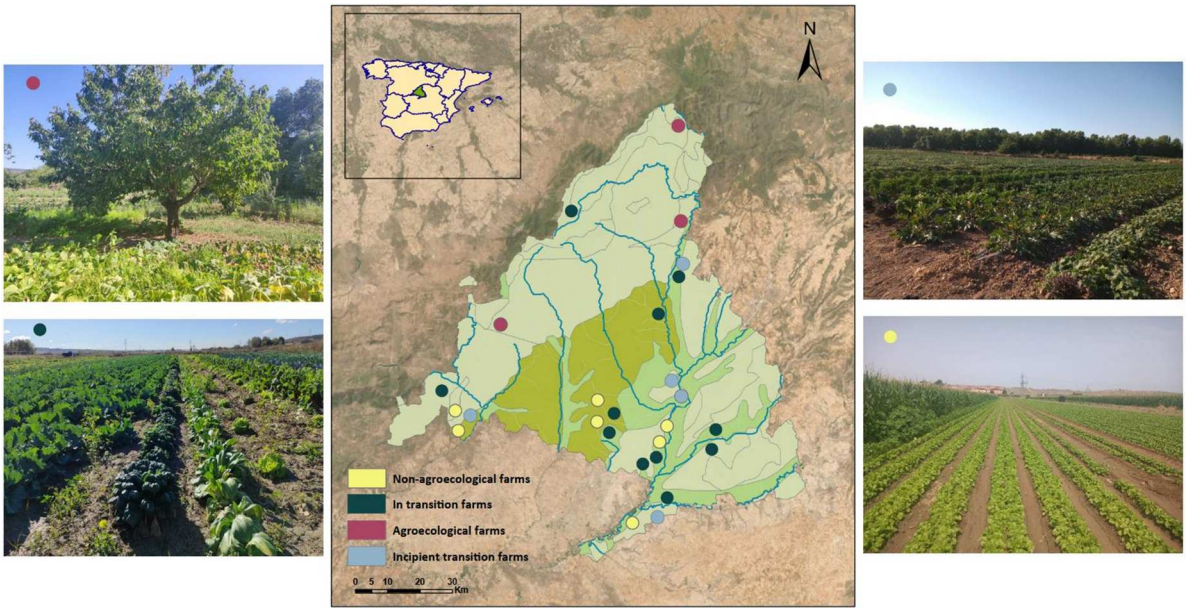

Figure 1. Map of the study area (Community of Madrid) with the 26 farms interviewed, the main rivers crossing the region and the dominant soil types (Afisol, Entisol and Inceptisol). The different coloured dots represent the four different farm groups. A represetantive photo is also included for each group of farms.

Culture and Food Traditions, Economy, Co-creation and Sharing of Knowledge and Responsible Governance (see Figure 2). While concrete data for Steps 2 and 3 were not available, the analysis of Steps 0 and 1 provided sufficient insight to address the objectives of the study.

We conducted 26 interviews between January 2022 and June 2023. Our study should be contextualized within the horticultural sector of Madrid, which has undergone a significant decline in recent decades, marked by a sharp reduction in the number of horticultural farms (Simón-Rojo et al., 2020). In this context, we believe that our sample provides an adequate representation of the specific geographical and socio-economic conditions of the remaining horticultural sector in the region. Moreover, while our study does not aim for broad statistical generalization, it does provide a comprehensive and relevant overview of the key barriers currently faced by horticultural farmers in Madrid, which is relevant in the context of agroecological transitions. Prior to the interviews, all farmers received in advance a document about research objectives and the interview process. They were provided with a document containing comprehensive research information and had to sign a consent form. The interviews were conducted by three researchers who utilized TAPE questionnaires and guidelines, which incorporated surveys and field observations as outlined in the FAO (2019) guidelines. Interviews ranged between 50 min and 1 h 40 min. All interviews were audio recorded after obtaining the consent of the interviewees and later transcribed.

2.3. Data analysis

The FAO´s 10 elements of agroecology were scored based on selected answers from the predefined options for each of the questions in the survey. The scores associated with a specific element were summed, and the resulting totals were standardized for each element. Based on the final CAET scores, we categorized the farms in four groups, following the classification proposed in Lucantoni et al. (2023): (i) advanced agroecological farms (CAET >70), (ii) farms in transition to agroecology (CAET: 50-70), (iii) farms in incipient transition to agroecology (CAET: 30-50), and (iv) non-agroecological or conventional farms (CAET <30).

We also identified the barriers expressed by farmers during interviews. To do so, we transcribed all interviews verbatim and subsequently imported and inductively coded them using the qualitative data analysis software NVivo. The coding of these barriers was conducted adapting the transformation domains of the conceptual framework proposed by Anderson et al. (2019), which delineated the agroecological transition across six domains of transition. Based on the barriers identified from the interviews we grouped them

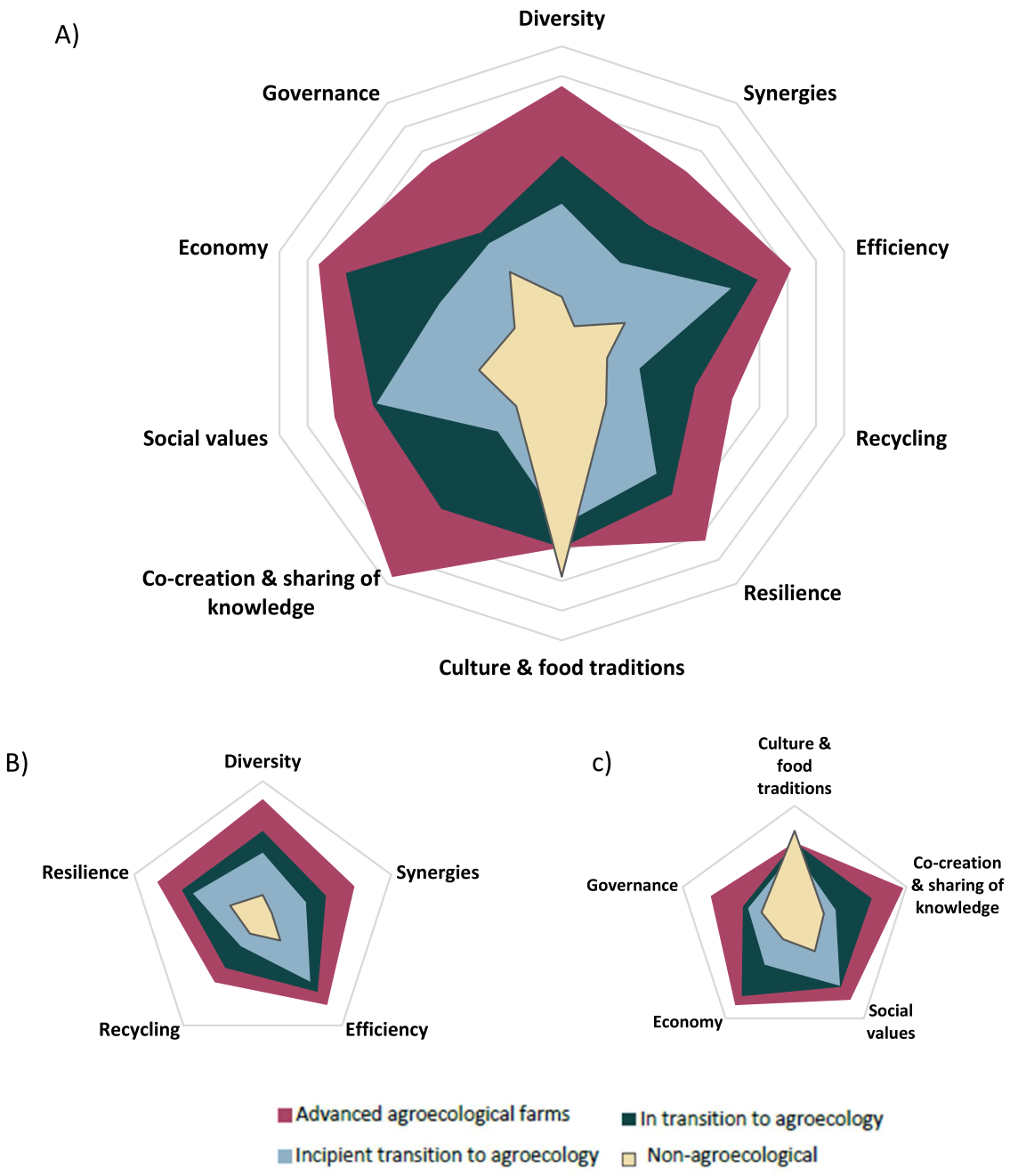

Figure 2. Mean scores for the 10 elements of agroecology among horticultural farms in the Community of Madrid are shown in figure (A). The four colours represent the different farm groups based on the CAET result. The elements are further divided in two groups, those more closely associated with farm management and environmental resources (B) and those concerning the social aspects of the farm (C).

into these domains: (1) access to natural resources and environmental resilience, (2) knowledge and culture, (3) economic challenges and systems of exchange, (4) social challenges and networking, (5) equity, and (6) policies and discourse (Table 2). We inductively coded the barriers within each domain and further categorized them into sub-codes based on the recurring themes gathered. Ultimately, we obtained 36 distinct sub-codes, encapsulating the entirety of information pertaining to barriers articulated by producers (see Table 2). In the results section, barriers are described per domain and verbatim excerpts have been employed to substantiate the presented information.

Agroecological literature has emphasized the need for exploratory studies where the goal is not to generalize beyond the study population, but rather to understand complex processes and identify emerging

patterns. In this sense qualitative and mixed methods research as the conducted here are not determined by large sample sizes but rather by capturing key variations within the studied population and reaching the theorical saturation (Iniesta-Arandia et al., 2014; Low, 2019; Vizuete et al., 2024). Accordingly, although we include quantitative components – such as frequency distributions and descriptive statistics, these are intended to enrich qualitative insights rather than to support large-scale generalizations. Mixed-methods research recognizes the value of quantitative descriptions even in small samples when they are interpreted within an appropriate qualitative framework (Creswell & Plano Clark, 2007). Therefore, rather than undermining our results, the sample size reinforces their validity and ensures our findings accurately reflect the experiences and challenges of horticultural farmers in Madrid.

3. Results

3.1. Characterization of the agroecological transition in the horticultural sector

The 26 farms were categorized into 4 groups, based on their CAET scores, with three farms in an advanced stage of agroecological transition (Mean = 78.9; SD = 10.4), 11 farms in transition stages (Mean = 61.9; SD = 10.6), five farms in incipient transition (Mean = 47.0; SD = 12.8), and seven classified as non-agroecological or conventional farms (Mean = 26.7; SD = 19.5).

The level of agroecological transition within the horticultural sector of Madrid is represented by the mean values of the four groups of farms for the 10 FAO elements (Table 1). The average CAET value, standing at 53.6, suggests that there remains considerable room for improvement in adopting agroecological systems. The most advanced element corresponds to Culture and Food Traditions, indicating that in general horticultural farms still conserve local varieties and strong traditional and local identity. Conversely, the two elements with the lowest scores are Recycling and Synergies. Most waste and by-products from farms are not being recycled, and farms are highly dependent on external inputs. The score is also influenced by the scarcity of alternative methods for water collection, a practice not commonly observed among the interviewed farms. Regarding Synergies, most farms only have horticultural production with low ecological connectivity to surrounding natural areas.

The advanced agroecological farms (Figure 2) have the highest CAET score in almost all the 10 elements of agroecological transition, except for Culture and Food Traditions (Table 1). Recycling shows the lowest value (60.4), but it is still high compared to other groups. The highest value is in Co-Creation and Sharing of Knowledge (97.2), which stands out significantly from the other groups. This indicates the presence of social mechanisms and networks that facilitate horizontal transfer of knowledge in agroecology. This is followed by Diversity, Economy, Resilience, Social Values, and Efficiency, showing a focus on agroecological practices and better preparation for external disturbances. In Synergies, these farms stand out due to multiple production systems in their farms, such as combining horticulture and fruit orchards, and sometimes including farm animals.

Table 1. Average scores for 10 elements of agroecology and the overall agroecological transition (CAET) for each of the farming groups assessed in the Community of Madrid.

	Diversity	Synergies	Efficiency	Recycling	Resilience	Culture & food traditions	Co-creation & sharing of knowledge	Social values	Economy	Governance	CAET
Advanced agroecological *(AdAgro)*	86.7	71.4	81.2	60.4	82.0	68.7	97.2	80.5	86.1	75.0	78.9
In transition to agroecology *(InTr)*	63.1	49.3	69.3	47.1	62.9	68.7	68.9	66.9	76.5	46.2	61.9
Incipient transition to agroecology *(InCp)*	47.0	33.6	60.0	27.5	54.2	61.2	36.7	65.5	43.3	41.7	47.0
Non-agroecological *(NonAgro)*	15.7	7.1	22.3	16.0	25.4	78.6	26.2	29.2	16.7	29.7	26.7
Average value	53.1	40.4	58.2	37.8	56.1	69.3	57.2	60.5	55.7	48.1	53.7

The second group is called farms in transition to agroecology, comprising most of the farms interviewed (n = 9). These farms averaged a CAET score of 61.9, indicating they are in the transition phase. The lowest scores were in Governance (46.2) and Synergies (49.3). Low governance scores reflect limited participation with other producers and lack of empowerment in local communities. The Synergies scores indicate attempts at managing soil-plants interaction with cover crops and crop rotation, but limited connectivity between agroecosystem elements and the landscape. Economically, these farms scored highest in Economy (76.5) due to selling part of their production to local markets and sometimes directly to consumers, outperforming the remaining two groups. The other elements (Diversity, Resilience, Efficiency, Social Values and Co-Creation and Sharing of Knowledge) scored above 60, suggesting both room for improvement and a good diversity of elements and a reduced chemical input dependency.

The third group of farms is referred to as an incipient transition to agroecology, indicating that they are in the early stages of change. This group consists of seven farms with an average CAET score of 47.1. The lowest scores were again found in Recycling (27.5) and Synergies (33.6), indicating that these farms do not extensively implement agroecological practices in the field. A notable difference from the previous groups is observed in the element of the Co-Creation & Sharing of Knowledge, which drops to a value of 36.7. Therefore, these farms could implement collaborative strategies with other producers to increase their knowledge in agroecology and sustainable agricultural practices. The elements of Economy, Governance and Diversity have similar values, contributing to a higher score in the element of Resilience (54.2). The score for Efficiency (60) suggests that they utilize external input in their farming practices selectively. The highest scores are attributed to Culture and Food Traditions, demonstrating a strong connection to their local area and the production of local varieties. Additionally, these farms also obtained high scores for Social Values, ensuring suitable working conditions and appropriate income.

Lastly, we have a group of farms (n = 7) that have not yet initiated the transition towards agroecology, referred to as non-agroecological farms. The average CAET score of these farms was 26.7, significantly lower than the other three groups. It is important to emphasize that all scores in this group are lower than those of the other groups, with only one notable exception: Culture and Food Traditions, which has the highest score of 78.6. This score suggests a strong traditional and local identity associated with the use of local varieties and dietary practices within conventional farms. Conversely, the elements with the lowest scores are Synergies (7.1), Recycling (16.1) and Economy (16.7), indicating the absence of agroecological practices in the fields and a limited focus on local consumers and local markets. For instance, all the farms in this group sell their production directly to the main primary logistics platform for fresh food in Spain ('Merca-Madrid'). The remaining elements (Social Values, Resilience, Governance, Efficiency, and Diversity) show similarly low values. This group of farms has considerable potential for improvement in relation to the implementation of agroecological practices.

3.2. Barriers for the agroecological transition

The interviews revealed obstacles that farmers encounter daily in their agricultural activities (see Table 2). We identified and documented these barriers as impediments to achieving a transition towards a more sustainable and equitable agri-food system. In total, we recorded 349 references of barriers grouped in 35 different barrier typologies. According to Anderson et al.'s (2019) transition domains framework, the most frequently referenced is economic challenges and systems of exchange (30.1%), significantly surpassing other domains. Subsequently, in descending order of frequency, are social challenges and networking (19.8%), policies and discourse (16%), access to natural resources (14.3%), knowledge and culture (13.5%), and finally, challenges linked to equity (6.3%).

The frequency of references varies across four farm groups (Figure 3). When examining the most common barriers, we found that in the advanced agroecological farms, 66.7% of them mentioned the main barriers such as: loss and changes in agricultural culture, lack of interest of decision makers, access to land difficulties, administration support, and climatic disturbances. In the farms in transition group, 63.6% of the initiatives mentioned lack of cooperatives and networking between producers, followed by difficulties in access to land (54.5%) and lack of economic profitability (54.5%). In the incipient transition groups, 60% mentioned lack of administration support, consumer awareness, professional

Table 2. The table presents the breakdown of codes and subcodes derived from the barriers extracted from the interviews. Six primary codes have been structured according to Anderson domains (2019). The table shows the number of barrier references, followed by the frequency of mentions categorized by groups. Additionally, the table provides the percentage of occurrences for each barrier, further organized by distinct groups of farms.

	References					% of cases			
Barriers	Total frequency	Ad-Agro	InTr	Incp	Non-Agro	Ad-Agro	InTr	Incp	Non-Agro
Economic challenges and systems of exchange	105	1	35	15	54				
Economically unfeasible	42	0	11	6	25	0.0	54.5	60.0	85.7
Distrust and dependence on intermediaries	18	0	5	1	12	0.0	36.4	20.0	85.7
Price of resources, inputs, and machinery	13	0	4	3	6	0.0	27.3	40.0	57.1
Consolidation of consumers and consumption groups	9	0	5	3	1	0.0	36.4	40.0	14.3
Too many different activities	9	0	4	1	4	0.0	27.3	20.0	28.6
Lack of logistics infrastructure	7	1	5	1	0	33.3	36.4	20.0	0.0
High market competence	7	0	1	0	6	0.0	9.1	0.0	42.9
Social challenges and networking	69	4	37	11	17				
Cooperatives and networking between producers	24	1	15	2	6	33.3	63.6	40.0	71.4
Generational succession	14	0	4	4	6	0.0	36.4	60.0	71.4
Communication with the administration	14	0	9	2	3	0.0	27.3	20.0	42.9
Integration with local communities	5	0	4	0	1	33.3	36.4	0.0	14.3
Lack of producers with similar mindset	7	2	3	2	0	33.3	27.3	40.0	0.0
Relation and communication with consumers	5	1	2	1	1	0.0	18.2	20.0	14.3
Policies and discourse	56	6	27	10	13				
Support to horticulture and alternatives systems	20	3	9	4	4	66.7	45.4	60.0	57.1
Mistrust of agroecology and ecological production	12	0	7	2	3	0.0	36.4	20.0	42.9
Complexity of CAP measures	9	0	6	2	1	0.0	45.4	40.0	14.3
Mistrust of the administration and CAP measures and dependency	**5**	1	1	1	2	33.3	9.1	20.0	28.6
Non-adapted regulations	**8**	2	3	0	3	33.3	18.2	0.0	28.6
Lack of recognition of the figure of the farmer	**2**	0	1	1	0	0.0	9.1	20.0	0.0
Access to natural resources and environmental resilience	50	7	13	4	26				
Access to land	13	3	9	0	1	66.7	54.5	0.0	14.3
Climatic disturbances	12	3	3	2	4	66.7	27.3	40.0	28.6
Depletion and lack of water	9	0	1	1	7	0.0	9.1	20.0	71.4
Increase in pests	8	0	0	1	7	0.0	0.0	20.0	57.1
Depletion of fertile soils	4	0	0	0	4	0.0	0.0	0.0	57.1
Climate change	4	1	0	0	3	33.3	0.0	0.0	42.9
Knowledge and culture	47	6	26	10	5				
Consumer awareness	16	1	9	4	2	33.3	45.4	60.0	28.6
Professional training for producers	13	1	6	4	2	33.3	36.4	60.0	28.6
Loss and changes in agricultural culture	9	2	4	2	1	66.7	27.3	40.0	14.3
Interest and knowledge of decision makers	5	2	3	0	0	66.7	27.3	0.0	0.0
Reference projects	4	0	4	0	0	0.0	27.3	0.0	0.0
Equity	22	1	7	7	7				
Conciliation	11	0	2	2	7	0.0	36.4	40.0	71.4
Lack of recognition for being a woman	5	1	2	2	0	33.3	0.0	40.0	0.0
Lack of women	4	0	2	2	0	0.0	0.0	40.0	0.0
Power relations	2	0	1	1	0	0.0	9.0	20.0	0.0
Agrarian contracts	0	0	0	0	0	0.0	18.2	0.0	0.0

training for producers, economic unfeasibility, and lack of succession. Finally, in non-agroecological farms, two main barriers were mentioned by the most respondents (by 85.7): economic unfeasibility and their distrust and reliance on intermediaries.

3.2.1. Economic challenges and systems of exchange

We identified seven sub-categories of economic challenges mentioned by farmers, detailed in Table 2. Notably, advanced agroecological farms exclusively highlighted economic barriers associated with deficient logistics infrastructure. Conversely, across the remaining categories, the most frequently cited obstacle was insufficient financial remuneration for agricultural labour. Farmers underscored low salaries, substantial economic risks, and, in many cases, incomes failing to exceed expenditures. Economic unfeasibility was mentioned by over 50% of those transitioning to agroecology, those in the initial phases of transitioning to agroecology (60%), and non-agroecological farms, with the latter indicating this concern in nearly all cases (85.7%). Farmers claimed: '*I´d better leave this … The costs are higher than the product. You must put money all the time. Man, 20 years ago the costs were lower, and you could even save something*

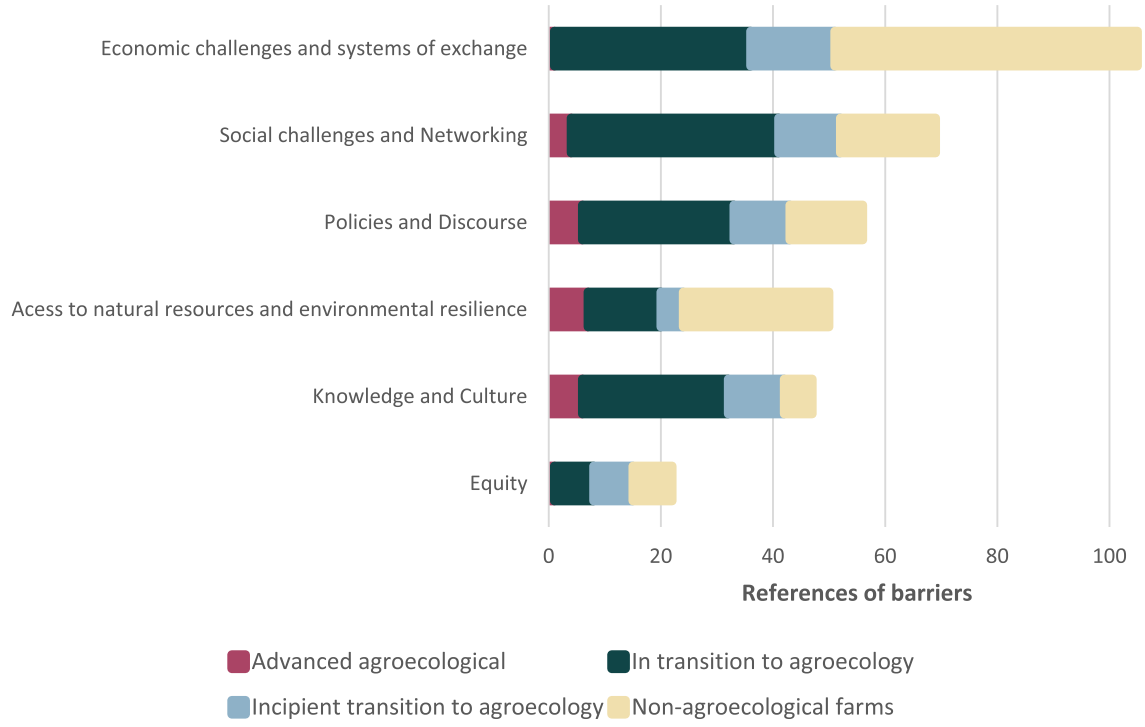

Figure 3. The figure illustrates the frequency of barriers cited within each domain, along with a comparative analysis of the citation counts across the four distinct groups of farms.

… ' (NonAgro4), '*Now it is easier to grow things, because we have new machinery, but before, my father sowed 1 ha, and with 1 ha he ate, but now? I need 10 ha to get the same as my father did with one!' (NonAgro3).*

The second most frequently mentioned economic issues is distrust and reliance on intermediaries within the value chain (with 18 references, Table 2). The non-agroecological farms often sell their produce through 'Merca-Madrid', Spain´s primary fresh food logistics platform. There, a designated individual adjusts the product prices and overseas sales. Farmers have expressed dissatisfaction with their inability to set fixed prices, which fluctuate significantly based on supply and demand dynamics (' *It is more interesting for us to sell it here to the consumers of Aranjuez than to sell it to Merca-Madrid. They set the prices … is an auction of our products …* ' – *InCp7*, '*Well, I had to stop producing 6 years ago, for two years, because we were sold to Merca-Madrid …* ' – *InTr8*). Other economic challenges included high costs of resources, inputs, and machinery; difficulty in maintaining long-term consumers bases; inadequate logistics infrastructure; and increased market competition attributed to the influence of products from other countries.

3.2.2. Social challenges and networking

The coding reveals a consistent pattern across all farm groups, underscoring social challenges and networking as an important barrier in Madrid´s horticultural system. Six main themes were identified in this domain (Table 2), emphasizing the need to address social issues across different horticultural systems.

The foremost barriers are the absence of cooperatives and networking opportunities among producers (24 references), coupled with a perceived lack of interest among younger individuals in sustaining farming in the future (14 references). Farmers feel isolated due to a lack of interest and a cultural deficit in fostering cooperative relationships in their production activities. This is echoed across the four groups of farms ('*None of the cooperatives worked, at least in this area. There was one here, but it did not work*' – *InCp8*). Except for non-agroecological farms, all groups struggle to find like-minded producers with similar values, hindering cooperatives formation and networking opportunities ('I *do not have collaborations here nor elsewhere. They have different production model than me … The X farm in the end are marketers who buy and sell in Merca-Madrid. I refuse to be a buyer-seller as I feel they are*' – *InCp3*).

Beyond the lack of cooperatives, three additional social challenges are highlighted mainly involving poor communication between stakeholders of the food system. Farmers reported limited engagement feel there

is a lack of communication with public administration, specially between irrigation communities and the hydrographic confederations concerning water use, leading to a sense of powerlessness and inefficacy in decision-making processes ('*In the case of the irrigation community it doesn't work, we don't meet or anything, we don't have any power to decide anything*' – *InTr4*). Agroecological farms (33.3%) and those in transition (36.4%) struggle to integrate into their local communities especially as newcomers to the areas. Finally, there is shared concern among all farm groups regarding the challenge of effectively communicating and engaging consumers in understanding their production systems.

3.2.3. Policies and discourse

The domain of policies and discourse encompasses six sub-categories (Table 2) related to policies, administrative roles within Madrid´s horticultural systems, perceptions of agroecology, and the acknowledgment of the farming profession. Two primary challenges were consistently mentioned across all four groups: the absence of support from the administration (20 references) and a pervasive distrust in both the administration and the Common Agricultural Policy (CAP) measures (12 references), which are notably correlated.

Numerous farmers expressed concerns regarding the lack of administrative support and emphasized the need for fostering agroecological initiatives ('*We need to move forward, but they cannot abandon the agricultural sector, we need solutions from them*' – *AdAgro1*). Some were frustrated by the absence of tailored measures for local horticultural systems, such as limitations on the size of cultivated areas, which are prerequisites for accessing CAP measures (' … *generally, the subsidies are for very large extensions. The criteria are very demoralizing, the subsidies are made so that those who have more get more, and this is not the case for the horticulturists … ' – InCp5)*. Moreover, measures like organic certification are deemed overly complex and costly, which outweigh the benefits.

Regarding farmers' discourse, noteworthy observations arose as certain individuals within the farming community exhibit skepticism towards the concept of agroecology and organic agriculture. They advocated for a separation of agricultural practices from social and political movements and emphasize a stronger focus on production issues ('*Agroecological projects suffer a lot from political ideas. At the beginning, the priority is to make it viable and then more*'; '*In my view, it has too many political overtones and this sometimes makes a certain sector of the population think that ecology is more of a political movement than what really is, which is a movement in defense of nature and the relationship between living beings. I tell you this because I believe that ecological agriculture as such should be seen as an aseptic discipline from the political point of view, and as a necessity … because nobody thinks that eating well is a political option, or going for a run to have a healthy body, well these are practices that exercise and benefit everyone's body, which are practices that we can call agroecological.' – InCp2*). This diverse range of perspectives highlights multifaceted attitudes towards agroecology, organic agriculture and the interplay between agricultural practices and political discourse.

3.2.3. Access to natural resources and environmental resilience

The study identified seven sub-categories of perceived barriers (Table 2) related to access to natural resources and the environmental resilience of agricultural initiatives. Non-agroecological farms faced these barriers more frequently than the others.

Access to natural resources is a significant barrier for agroecological (66.7%) and in transitioning farms (54.5%), particularly in securing new production areas, as many do not come from traditional family backgrounds ('*To start a project like this the first thing you need is land and the community of Madrid has to liberalize farmland*.' – *AdAgro3*). Conversely, non-agroecological farms (71.4%) predominantly highlight water scarcity and usage restrictions ('*We have a lot of problems with water. Look, they cut off the water too early. In the meantime, without water, what can I plant? If it doesn't rain, it will be a disaster*' – *NonAgro5*). They also perceive a depletion of fertile soil (57.1%), potentially stemming from prolonged land use and specific agricultural practices affecting soil and ecosystem services. Pest infestation concerns are shared by non-agroecological farms and some in the initial transition, possibly linked to the use of agrochemicals which can exacerbate pest issues.

All farm groups unanimously cite the impact of climatic disturbances as a significant barrier (12 references). Incidents such as a snowstorm in Madrid or early spring frosts pose significant risk to farming activities and production.

3.2.4. Knowledge and culture

Within the knowledge and culture domain, our analysis identified five sub-categories (see Table 2), whit non-agroecological farms facing fewer barriers compared to other groups. Common challenges include consumer awareness (16 references), professional training (13 references), and shifts in agricultural culture (9 references). A central challenge is the pivotal role consumers play in the agricultural value chain. Farmers struggle to gain visibility in local communities and foster connections with consumers to promote their initiatives. Lack of consumer awareness about local agricultural offerings hinders farmers' ability to market products effectively ('*It is crucial to educate the consumer, to make them understand how the products are and when they are available, otherwise it is really difficult … ' – InTr1)*.

All farm groups expressed the need for professional training, desiring accessible courses on topics like organic production and innovative practices. Farmers cite deficiencies in technical knowledge as a barrier to progress ('*In Spain we are underdeveloped in terms of agricultural training … , I had to go outside Spain for training.' – InTr6, 'Well, horticulture is a discipline of which very little is known, everyone knows that you plant lettuce on the balcony and so on, but the art of cultivating the land in a better way, with guaranteed success, there is a clear lack of knowledge of what constitutes the discipline of horticulture itself, due to lack of references or public outreach programs' – InCp2*).

3.2.5. Equity

The domain of equity emerges less frequently in farmers´ challenges (22 references in total), but it is crucial for the transition to agroecological systems. The underrepresentation of women in the interviewed initiatives contribute to the lower frequency of its mention.

A primary challenge in this domain is work-life balance. Farmers struggle to find time for family responsibilities, including breaks on weekends or holidays, due to the demanding nature of their work. Another prominent barrier, especially highlighted by women involved in the initiatives, is the perceived lack of recognition for their contributions within the agrarian sector. They express frustrations about the need to continually prove their capabilities and expertise, facing skepticism and gender-based bias in a predominantly male-dominated field. Instances of disbelief or dismissiveness towards their roles and responsibilities undermine their sense of recognition and validation within the sector ('*You must prove everything you do. The sheep are mine and they are in my name, but until they recognize your work.' – AdAgro1*). Subsequent challenges include the scarcity of women engaged in these initiatives, power dynamics among members, and complexities in navigating agrarian contracts.

4. Discussion

4.1 Steps towards agroecological transition in Madrid

Following the FAO´s TAPE tool methodology, we illustrated the heterogeneity among farmers at various transition stages within this territory. Based on our sample, the average CAET index is 53.7, which could be interpreted as indicative of an initial transition phase, highlighting a potential need for further development in agroecological practices.'. A similar study in the peri urban area of Buenos Aires and La Plata (Argentina), which also examined horticultural systems, including conventional and agroecological management, reported a similar average value for the CAET index (46.0) (Sokolowski et al., 2024).

The 10 elements described by FAO have been previously interconnected with other frameworks used to analyse farmer´s progression towards agroecological transition (Gliessman et al., 2007; Hill & MacRae, 1995; Wezel et al., 2020). It is crucial to note that these frameworks do not depict linear processes, as transitioning between levels does not necessarily occur sequentially. Farmers may adopt practices from different levels based on their situation, the environment and history as producers (Gliessman et al., 2007). This is clearly reflected in our data, where practices associated with initial levels, directly influenced by farmers' decisions (e.g. Recycling or Synergies), have lower average values compared to elements linked with advanced levels

(e.g. Culture & Food traditions, Co-Creation, and Sharing of Knowledge or Social Values), which are influenced by diverse contextual factors and decision-making. Following these two elements are Efficiency and Resilience, which are directly linked with the performance of the farmers in their properties, and more related to initial stages of the transition (Gliessman et al., 2007). Other studies employing the same tool have also found non-linear processes of transitions, where elements related to farm management and innovation do not necessarily rank higher than those associated with the socio-cultural aspects of the farms (Barrios Latorre et al., 2023; El Mujtar et al., 2023; Gomori-Ruben & Reid, 2023; Sokolowski et al., 2024).

We found notable differences in the values attributed to the elements within the four identified groups of farms, providing a basis for identifying strategies tailored to each group to promote agroecological transition. Farms in a more advanced stage of transition (depicted in pink, Figure 2), exhibit the highest value in the element of Co-Creation and Sharing of Knowledge (97.2), aligning with Sokolowski et al. (2024). In our case, these initiatives in this group have worked towards establishing social mechanisms that facilitate horizontal creation and transfer of knowledge. This suggests that agroecological farms prioritize social innovations related to the political discourse aspect of agroecology, in addition to strictly agricultural practices. Farmers explained their involvement in a network of agroecological producers within the Community of Madrid, known as AUPA (United Association of Agroecological Producers), which paves the way for horizontal knowledge creation and transfer through mutual support. Conversely, this element does not emerge prominently in other groups, where the absence of cooperatives and networking opportunities is identified as a primary barrier among producers. Farmers cited isolation in their production activities due to the lack of cooperative tradition. Co-created knowledge yields more applicable and long-lasting results rather than knowledge transferred through top-down mechanisms (Méndez et al., 2017; Utter et al., 2021). Incorporating local and traditional peasant knowledge is essential for transforming agri-food systems (Cuéllar-Padilla & Calle-Collado, 2011; Méndez et al., 2017; Warner, 2006). Consequently, fostering a supportive environment through established regional networks to share experiences and knowledge, such as the farmer-to-farmer movement (Rosset & Martínez-Torres, 2012) or the promotion of participatory guarantee systems (Grovermann et al., 2024) might serve as a pivotal driver for amplifying the agroecological transition in Madrid. These processes indirectly promote channels of communication between producers and local administration, also identified as a significant barrier in the present study.

In relation to the other social elements analyzed, it's noteworthy that non-agroecological farms slightly stand out in the element of Culture and Food Traditions among the other three groups, with the highest value (78.6). The other three groups of farms also have a relatively high value in this element, indicating that all farm groups have an interest in their food culture in our region. Non-agroecological farms may have higher values in this element due to their roots in family farming backgrounds, engaging in this activity for a longer period. As observed in the interviews, many of these farms have experienced the transition from more traditional agriculture to current intensified systems. Despite this shift in agricultural practices, it appears that cultural traditions such as the use of traditional varieties and their cultivation and consumption methods have been maintained over time. This emphasizes the importance of recognizing and including the expertise and traditional knowledge of conventional farms in the transition towards agroecology. Collaboration with all farming communities is crucial to acknowledge the importance of cultural heritage and strengthen the collective effort towards more sustainable, fair, and resilient agri-food system (Dumont et al., 2020; Teixeira et al., 2018). Indeed, traditional knowledge of non-agroecological famers could be very useful for the agroecological sector. Our study, along with previous research in the region (Palomo-Campesino et al., 2021), shows that agroecological producers usually do not come from farming roots but are new farmers with high interest in agroecological practices. Therefore, the collaboration and exchange of knowledge between non-agroecological and agroecological farmers play a pivotal role in fostering a more sustainable and resilient agri-food system.

4.2. Barriers and challenges to address transition

To bring about change, the first step involves harbouring the desire to initiate it and the intent to take actions towards the desired change. Scientific discourse emphasizes that intention, motivation, and willingness constitute the initial step towards effecting change (Dessart et al., 2019; Mills et al., 2017; Ryschawy et al., 2019). Therefore, the initial phase of agroecological transition is that those directly engaged in the agri-

food system, such as producers, consumers, or policy makers, are persuaded about the need for system change. Although not explicitly identified as a barrier, a significant obstacle observed during interviews is the lack of conviction among conventional farmers regarding the necessity of transition towards more sustainable systems. For example, some producers revealed that they do not have the willingness to transform the system due to a lack of resources or age of farmers. Typically, these farmers who come from traditional backgrounds, often from families with a long history of farming, sometimes exhibiting insecurity and distrust towards 'new' systems (including agroecological production). This tendency may be linked to the fact that a significant proportion of these individuals experienced the consequences of the Green Revolution (Borlaug, 1971), where their agricultural systems were transformed into the hegemonic intensive production model. Moreover, changes imposed by public authorities are often met with resistance within the sector, further exacerbating distrust (Anderson et al., 2019). To address this substantial barrier, strategies should prioritize promoting communication channels and providing technical advice within the horticultural sector. An illustrative example is the introduction of 'horticultural advisor' in the Community of Madrid, a professional who offer guidance by visiting farms. These actors must possess a holistic perspective on the sector and simultaneously act as information brokers among the farmers. This reflects the importance of trusted advisors in generating social capital, fostering communications, and ensuring positive long-term change to support the agroecological transition (Zawalińska et al., 2022).

Economic sustainability emerges as a recurring concern and primary obstacle among farmers across all farms' group in Madrid horticultural sector. Among these concerns is the lack of economic profitability within the profession, a lack of trust among stakeholders in the supply chain, and the high cost associated with necessary resources. Economic challenges also represent a primary barrier for transitions to agroecology in other agricultural systems (Dessart et al., 2019; Frison, 2016; Gava et al., 2022; Horrillo et al., 2021; Padel et al., 2018), and in other horticultural systems analyzed (Palomo-Campesino et al., 2021; Polonio Punzano et al., 2021; Yacamán Ochoa, 2020). Ensuring economic sustainability of initiatives stands out as a prerequisite for initiating an agroecological transition (van der Ploeg et al., 2019). Ensuring economic viability is critical not only for individual initiatives but also for the broader success of the agroecological transition.

While economic aspects are less frequently mentioned among agroecological farms, this does not imply an absence of economic challenges. This may be related to the fact that farmers engaged in more agroecological practices might feel more satisfied with their work and its outcomes compared to those in conventional systems(Xiang et al., 2025). Hence, we consider it important to highlight the economic model adopted by the agroecological initiatives, as it diverges from the conventional approach and holds potential as a solution to address economic challenges. Two out of three initiatives within this group operate as CSAs (Community Supported Agriculture), a community-based organization model for food production (Espelt, 2020). This system involves the hiring of professionals to conduct agricultural activities (growers) with the assistance of association members. Consequently, all participants receive a share of the weekly production. This arrangement mitigates economic uncertainties through collective support among association members. In addition, membership and prices are fixed, which also allows for economic security and an annual planning of the quantity to be produced. When questioned regarding the purpose of their production, one of the producers from these initiatives responded: '*No, we do not sell; all production is for self-consumption, but for 150 families. Here, the project owners are the members-families organized to produce their food. They pay a fee to enable producers to carry out their work, not for the food. You take what is available*'. This model is based on cooperative self-sufficient rather than commercial sales and underscores a distinctive approach to address economic challenges within the agroecological framework, demonstrating a potential for alternative models to provide both sustenance and economic viability (Opitz et al., 2019; Zhen et al., 2020). Moreover, beyond ensuring economic stability, these initiatives actively foster environmental and social sustainability within the regions where they are established (Paul, 2019; Vicente-Vicente et al., 2023).

Another potential solution to achieve economic sustainability is to promote diversity of income sources, which is mentioned by agroecological farmers but also by the groups of farms in transition to agroecology. These farms not only sell the products they produce but also rely on training activities or guided tours, among others. Diversification is a common solution and strategy within agroecological approaches.

A barrier highlighted in both agroecological and in transition to agroecology farm groups is the access to land. Agroecological farms particularly emphasize the difficulties they encounter when initiating farming

activities, contrasting with conventional farms with established family traditions in agriculture. This issue is widely recognized in other regions (Anderson et al., 2019; Carlisle et al., 2019), but it is also widespread across various agricultural regions in Spain (González-Rosado et al., 2021; MAPA, 2021; Moran Alonso, 2015). This problem may be exacerbated in territories experiencing high urban pressure, like the Community of Madrid, where horticultural areas face potential threats from urban development (Zimmerer et al., 2022). On the other hand, conventional farms, originating from family agricultural backgrounds, possess larger land holding and facilities in accessing new agricultural land. This underscores the importance of establishing networks and communication among diverse horticultural farms, regardless of their management practices. Moreover, our data reveals that farms engaged in agroecological production tend to involve more young individuals and women. Hence, addressing this situation from a political standpoint becomes crucial. Facilitating access to land for agroecological producers could potentially alleviate other identified barriers in this study, such as the lack of generational succession prevalent among conventional producers and the underrepresentation of women in surveyed initiatives (Vizuete et al., 2024). An example of a municipal policy addressing this barrier is the Agroecological Park of 'Soto del Grillo', an agricultural area of public land reserved for agroecological production. This project aims to promote the creation and stabilization of economic projects in the field of agroecology, which allows access to healthy food for the citizens of the municipality, generating decent working conditions for producers and adding value to the landscape in which the park is located (Yacamán Ochoa & Zazo Moratalla, 2015).

Finally, this discussion not only identifies barriers but also proposes potential solutions, leveraging examples from existing initiatives, to aid external readers in addressing challenges within the agri-food system. It is essential to highlight these examples to disseminate and replicate viable solutions effectively, particularly considering that many existing solutions may be overlooked. By sharing and implementing successful strategies, we can work towards reconstructing and guiding our agri-food system towards sustainability and resilience.

5. Conclusions

This study uncovers the heterogeneity among horticultural farms in the Community of Madrid, highlighting the varied stages of agroecological transition. By examining 10 elements of agroecology, we observe non-linear progression in the transitions, identifying four different groups of farms. Advanced agroecological farms exhibit high values across diverse social elements such as Co-creation and Sharing of Knowledge, Governance and Social Values. Moreover, such farms also showed higher values in elements closely associated with agricultural practices, including Efficiency, Synergies, and Diversity. Conversely, non-agroecological farms display the highest value in Culture and Food Traditions. We posit that fostering collaboration and communication between initiatives could serve as a strategic approach to promote agroecological transition by addressing common challenges across the horticultural sector. Established agroecological farms could contribute by sharing experiences on network building, while conventional farms could provide valuable insights into traditional practices, historical knowledge, and land ownership.

Interviews conducted during the study revealed a diverse range of barriers hindering agroecological transition, including the lack of trust in the change, concerns about economic sustainability and challenges related to difficulties in access to land. Addressing these barriers necessitates tailored strategies for effective change. Noteworthy solutions, such as evidenced by examples such as CSAs, support from municipal policies, and horticultural advisors, underscore the potential for overcoming obstacles and promoting the agroecological transition in the Community of Madrid. In essence, we believe that this research not only contributes valuable insights into the dynamics of agroecological transition but also underscores the significance of collaborative efforts and tailored strategies in steering the horticultural sector towards a more sustainable and resilient future.

Author contributions

CRediT: **Inés Gutiérrez-Briceño:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing; **Irene Pérez-Ramírez:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Validation, Visualization, Writing –

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the 2019 call for grants for R&D projects for young researchers of the Universidad Autonoma de Madrid Autónoma de Madrid with the proyect SAVIA-Sembrando AlternatiVas de Innovación Agroecologica under Grant [SI1/PJI/2019-00444], by MCIN/AEI/10.13039/501100011033/FEDER, EU, in the Agrolandscale project under Grant (PID2022-138972OA-I00), and from the European Union's Horizon 2020 Research and Innovation Programme Contracts 2.0 under the grant agreement No 818190. We would like to express our gratitude to all participating farmers who have taken part in this project. Ministerio de Ciencia, Innovación y Universidades

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